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The efficacy of an iterative "sequence of prevention" approach to injury prevention by a multidisciplinary team in professional rugby union

Jason C. Tee, Sheree Bekker, Rob Collins, Jannie Klingbiel, Ivan van Rooyen, David van Wyk, Kevin Till and Ben Jones

ABSTRACT

Objectives: Due to the complex-systems nature of injuries, the responsibility for injury risk management cannot lie solely within a single domain of professional practice. Interdisciplinary collaboration between technical/tactical coaches, strength and conditioning coaches, team doctors, physical therapists and sport scientists is more likely to have a meaningful impact on injury risk. This study describes the application and efficacy of a multidisciplinary approach to reducing team injury risk in professional rugby union.

Design: Observational longitudinal cohort study.

Methods: Epidemiological injury data was collected from a professional rugby union team for 5 consecutive seasons. Following each season, this data informed multidisciplinary intervention strategies to reduce injury risk. The effectiveness of these strategies was iteratively assessed to inform future interventions. Specific examples of intervention strategies are provided.

Results: Overall team injury burden displayed a *likely beneficial* decrease (-8 %; injury rate ratio (IRR) 0.9, 95%CI 0.9 to 1.0) from 2012 to 2016. This was achieved through a *most likely beneficial* improvement in non-contact injury burden (-39 %; IRR 0.6, 95%CI 0.6 to 0.7). Contact injury burden was increased, but to a lesser extent (+18 %; IRR 1.2, 95%CI 1.1 to 1.3, *most likely harmful*) during the same period.

Conclusions: The range of skills required to effectively manage complex injury phenomena in professional collision sport crosses disciplinary boundaries. The evidence presented here points to the effectiveness of a multidisciplinary approach to reducing injury risk. This model will likely be applicable across a range of team and individual sports.

Key words: Injury prevention, rugby, multidisciplinary, complex systems

INTRODUCTION

Injury is a known issue in professional rugby union, with overall incidence estimated at 81 injuries per 1000 playing hours in the professional game[1]. Recent research within rugby union[2] and other sports[3] has shown links between team injury burden and performance. In order to increase performance, therefore, it is imperative that injury burden be reduced.

Injuries result from complex interactions between a variety of internal and external risk factors[4]. Bittencourt and colleagues[5] recently presented a multi-factorial complex-systems model for sports injury prediction, consisting of emerging patterns of injury determined by risk or protective regularities, and a highly complex 'web of determinants'. Sports injury prevention outcomes, on this view, are influenced by several factors, including "intrapersonal, interpersonal, organisational, community, and societal factors"[6]. Sports injury prevention, therefore, is best understood as a complex task, undertaken within a complex environment[6].

Due to this inherent ontological complexity, the responsibility for injury prevention should not rest solely within a single domain of professional practice[7]. Full utilization of the diverse skillset available within a multidisciplinary team (MDT) is likely to have a meaningful impact on reducing injury in real-world professional sport settings. Although research within the field is limited, some case studies have already illustrated that the MDT approach can have notable impact on injury outcomes in elite sport[8,9]. These case studies highlighted that single discipline reductionist approaches are unhelpful, and noted that rich communication and collaboration between coaching and sports medicine teams was essential for injury reduction. In this way, medical, sport science, strength and conditioning and coaching staff all make an important contribution to enhanced team performance by minimizing time lost to injury[10]. Previous research has described how multidisciplinary systems could be set up to improve high performance sport structures[8,9], but have not empirically assessed their effectiveness nor described their implementation as an ongoing process. The aim of the current article is therefore to describe the process and efficacy of a real-world, multidisciplinary, iterative injury prevention approach, undertaken within a professional rugby union team over five consecutive seasons.

METHODS

This research was conducted in a professional South African Rugby Union team competing in the Super Rugby and Currie Cup competitions. The University of Johannesburg's ethical review committee granted ethical approval for this research, and permission to publish historical injury data was provided by the Golden Lions Rugby Union. All research was conducted in accordance with the Declaration of Helsinki (2013). Over the course of the research period (2012 to 2016), 102 different players (mean stature 186 ± 7 cm, body mass 105.6 ± 11.7 kg) represented the team in senior competition. The team's results during the research period are summarised in Table 1.

<Insert Table 1 here>

The MDT consisted of three technical/tactical coaches, a strength and conditioning coach, team doctor, physiotherapist, biokineticist and sport scientist. The MDT composition is typical of the support staff available to a professional rugby team.

The Sequence of Prevention[11] informed the conduct and reporting of this study. This model was developed to guide injury prevention research studies in the sporting context, and consists of four steps: 1) establish the extent of the problem, 2) establish aetiology and mechanisms of injury, 3) introduce preventive measures, and 4) assess effectiveness by repeating stage 1[11].

The steps of the Sequence of Prevention were initially applied and then repeated year on year as an iterative, responsive process, that continues within the current team structure (Figure 1). Complexity theory underpinned the assumptions guiding the injury prevention approach, in that the context and setting were theorized to be open systems, underscored by such aspects as non-linearity, feedback loops, and the ability to evolve, learn, and adapt[6]. This allowed for a real-world responsive and iterative approach to be developed and implemented, as the needs of the rugby team were uncovered and evolved in response to the evolving intervention approach itself. Out of necessity, the injury prevention strategy was constantly refit in response to changing factors within the system. These factors included changes in playing and coaching staff, competition structure, law changes, evolving game demands, and unanticipated effects of intervention strategies. All injury prevention strategies were based on retrospective data, but expert foresight allowed for some measures to be proactively adopted in anticipation of emerging challenges. The process is described in the following sections.

<Insert Figure 1 here>

Step 1 - Establish the extent of the problem. Step one of the Sequence of Prevention is to conduct injury surveillance. In this study, the team doctor collected data for all injuries during the observation period. Injury data were collected in accordance with the "time-loss" injury definition in the International Rugby Board consensus statement on injury data collection procedures[12]. Injury burden was calculated as the total number of days that players were unavailable due to injury across a whole season. Further data collected related to the site and type of injury, as well as to whether injury occurred during contact or non-contact events[12]. An injury audit was completed for each season for the duration of the study. The primary data set used to inform interventions throughout this study, therefore, was seasonal team injury outcomes.

Injury burden was normalized to a 32-week season to account for differences in the number of playing weeks in different seasons. 95% confidence intervals were calculated using standard equations[13]. Injury rate ratios (IRR) with 95% confidence intervals and magnitude-based inferences (MBI) were used to determine differences in injury burden across seasons. MBI represents the likelihood that the true value is substantially positive or negative according to the following scale - <1%, most unlikely; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possibly; 75% to 95%, likely; 95% to 99%, very likely; >99%, most likely[14]. The threshold for significant benefit or harm was set at 5%.

Changes were considered meaningful if the likelihood of positive or negative change was greater than 75% (i.e. possibly, likely, very likely or most likely)

Step 2 - Establish aetiology and mechanisms of injury. In the context of a professional sports environment, the time and resources required for objective investigation of the mechanisms of injury was not available. Instead, expert-opinion (based on the knowledge and expertise of the MDT), rather than an investigative approach was used to determine injury aetiology. Where possible, these opinions were informed by published research and objective data such as video footage or training load data. For example, non-contact muscular strain type injuries were attributed to overuse/inadequate recovery causes, while injuries from direct trauma were attributed to contact involvement.

Step 3 - Introduce preventive measures. Following the initial injury audit, and similarly following the injury audit each season, a series of inclusive "risk assessment"[15] meetings took place, incorporating all members of the MDT. These meetings had the aim of determining the best areas for injury prevention intervention based on the results of the injury audit. MDT members presented potential injury prevention strategies from within their area of expertise and experience. These prevention strategies were regularly informed by recent research and through discussions of best practice with other colleagues in the field. Interventions were pragmatically assessed both on the basis of potential to reduce team injury burden, and in the context of resources and time available to affect the intervention. This approach ensured pragmatic solutions, responsive to the complexity of the context and setting. The most appropriate injury prevention interventions were selected, and delivered by the relevant members of the MDT, during training, over the course of a season. This step is further described in the discussion of this article.

Step 4 - Assess effectiveness by repeating stage 1. Following the initial injury audit in 2012, continuous, longitudinal observation of team injury outcomes was conducted over successive seasons (2013 to 2016). Injury audits were undertaken each season at the conclusion of competition, and were used to assess the effectiveness of interventions. Previously implemented intervention strategies were assessed and either continued, discontinued or modified based on their effect in the subsequent injury audit.

RESULTS

During the 5 seasons (2012 to 2016), a total of 691 injuries were documented for a cumulative injury burden of 11,275 days. During this period the team was involved in competitive training (non-preseason) for a total of 165 weeks, and played a total of 132 matches. The mean season injury burden throughout this period, was 2255 (95%CI 2162 to 2348) days. The mean injury burden per season (2012 to 2016) is presented in Figure 2a. Team total injury burden displayed progressive improvements from 2013 to 2016 (-14%; IRR 0.9, 95%CI 0.8 to 0.9, *most likely beneficial*) (Figure 2a).

<Insert Figure 2 here>

The first iteration of the sequence of prevention approach resulted in a 42% decrease in non-contact injuries (IRR 0.6, 95%CI 0.5 to 0.6, *most likely beneficial*), and a concomitant 49% increase in contact injuries (IRR 1.5, 95%CI 1.4 to 1.6, *most likely harmful*). Overall, this amounted to a small increase (≈7%) in total injury burden from 2012 to 2013 (IRR 1.1, 95%CI 1.0 to 1.1, *likely harmful*). Following this first iteration (2012 to 2013), the burden of non-contact injuries stabilized at approximately 680 (95%CI 630 to 730) days for the following three seasons. Over the same time period (2013 to 2016), progressive decreases in contact injury burden were apparent (-21%, IRR 0.8, 95%CI 0.7 to 0.8, *most likely beneficial*).

Figure 2b illustrates the contribution of injuries at particular injury sites to overall injury burden in each of the 5 seasons studied. The 6 most injurious sites overall are included in the graph. Concussion injury burden was meaningfully reduced by 87% from 2013 to 2016 (IRR 0.2, 95%CI 0.1 to 0.3, *most likely beneficial*). Posterior thigh injury burden was meaningfully lower in 2015 and 2016 compared to 2012 to 2014 (-61%, IRR 0.3, 95%CI 0.2 to 0.4, *most likely beneficial*). Ankle injury burden was increased from 2012 to all other seasons, but 2015 and 2016 were meaningfully lower than 2013 and 2014 (-51%, IRR 0.6, 95%CI 0.5 to 0.7, *most likely beneficial*). Lower leg/Achilles injuries were meaningfully reduced in 2013, 2015 and 2016. Other injury sites displayed differential results. Knee injury burden was meaningfully lower than the median value (2014) in 2013 and 2016, but meaningfully greater in 2012 and 2015. Similarly, shoulder/clavicle injuries were significantly greater than the median (2016) in 2013, but meaningfully reduced in 2014 and 2015.

DISCUSSION

This research has shown that a reduction in team injury burden can be achieved in a real-world professional rugby union setting, through an iterative multidisciplinary approach. The reduction in injury burden achieved corresponded with marked improvements in team playing performance over five seasons. This is a positive and encouraging addition to sports injury prevention literature, demonstrating that such real-world approaches in complex settings are effective.

Next, we discuss in more detail the implementation of the injury prevention approach used, as informed and underpinned by the methods described above.

The results of the 2012 season injury audit revealed that the team was experiencing greater player-time losses due to injury than expected for senior men's professional teams[1]. Additionally, the team performed poorly in 2012 and the high injury burden was identified as a cause. As a result, both coaches and medical staff committed to engaging in the process of reducing team injury burden.

Analysis of the 2012 injury audit identified areas where the application of injury prevention interventions may be successful in reducing team injury burden. Foremost among these was the time lost to non-contact injuries - 46% (982, 95%CI 920 to 1043 days) of total injury burden (Figure 2a). Previous research had demonstrated that high training loads and inadequate recovery are risk factors for non-contact soft tissue injury[16]. Therefore, since these are manageable factors, this presented a good target for the initial injury risk intervention.

The MDT, through step 2, determined that the historical training prescription of the team was suboptimal, and a number of multidisciplinary strategies were employed to optimize training prescription. Preseason training loads were reduced based on the evidence of Gabbett (2004)[17]. Microtechnology (GPS and accelerometers) was used to better align training practices with match exertions[18]. Players were screened for muscular strength imbalances and movement pattern dysfunctions[19]. In cases where these were identified, corrective training programs were implemented. A perceptual-fatigue monitoring program, making use of weekly questionnaires, was implemented to monitor players' training responses. Training was then continually modified in response to increased perception of fatigue. The rehabilitation/return-to-play process was examined for inefficiencies and innovative processes, such as hyperbaric oxygen therapy[20] and plasma-rich platelet therapy[21] were introduced to accelerate recovery. High-level scientific evidence of the efficacy of these approaches is not yet available, but positive effects were observed in this environment.

Other areas identified by the MDT for the implementation of injury prevention interventions were the burden of knee and lower leg / Achilles injuries (Figure 2b). Season 2012 injury data showed that 10 non-contact knee injuries had occurred for a total injury burden of 532, 95%CI 487 to 577 days (supplementary data). This equated to 24% of the team's total injury burden. Research has demonstrated the efficacy of neuromuscular training programs for reducing the incidence of non-contact lower limb injuries[22]. Following from this, the team warm up was adjusted to include a number of dynamic stretching, jumping, agility and balance tasks.

The effect of the injury prevention interventions in 2013 was mixed. The 2013 injury audit indicated that a 42 ± 4% reduction in non-contact injury burden had been achieved (Figure 2a). This was largely the result of a 64 ± 4% reduction in knee and a 59 ± 6% reduction in lower leg / Achilles injuries (Figure 2b). These results pointed to the success of the improved training and monitoring programs. However, in the same period, there was a 49 ± 7% increase in contact injury burden, resulting in a 7 ± 5% increase in overall team injury burden (Figure 2a). Further reasons for the increased contact injury burden were meaningful increases in the burden of shoulder / clavicle and ankle injuries (Figure 2b). The majority of these (96%) were contact mechanism injuries.

Following the 2013 season, all injury mitigation strategies were retained based on the successful reduction of non-contact injuries. The MDT reasoned that an increase in contact injuries was the natural result of increased exposure to competition and contact events resulting from the decrease in non-contact injuries. For example, there was a 55% increase in contusion type injuries in 2013 (supplementary data). Contusion injuries generally required players to be placed on modified training (non-contact) for one to two days and as a result increased the recorded contact injury burden by 96 days. The system[23] had been modified and by reducing time lost to non-contact injuries, and therefore increasing players exposure to potentially injurious events during matches and training. This required further refinement of the injury risk mitigation strategy, and forced the MDT to consider whether contact injury risk could be modified.

Some previous research has excluded contact injuries from risk assessment strategies because these injuries have been seen as "inevitable" or "unavoidable" and unrelated to training load[24]. However, evidence has begun to emerge that contact injuries may be related to movement quality[18], skill[25], and fatigue[26] factors. Therefore, mitigation strategies were developed to specifically address these contact injury problems. It was determined that some of the shoulder injury burden may be related to insufficient shoulder strength among the players[27]. Team strength training was adjusted to improve this parameter. Review of the mechanism of injury occurrence demonstrated that a number of shoulder injuries were the result of players performing tackles in sub-optimal body positions. This led to a coaching intervention where greater emphasis was placed on correcting technical components of the tackle.

An understanding emerged that some of the contact injury burden was related to the game plan that the team employed, where players in certain positions were regularly required to carry the ball into contact. It was a challenge to keep these players injury free because of how regularly they were tackled. In addition, physical profiling of the squad revealed that the available personnel were unlikely to physically dominate opponents and that a game plan based on skill and ball movement might be more effective for this team. Based on this and other tactical drivers, the game plan evolved to place more emphasis on avoiding contact and moving the ball into space.

In addition to the contact injury problem, the MDT was concerned about the burden of injuries in the lower leg and ankle complex. Although lower leg injuries had been reduced in 2013, the burden of ankle injuries was significantly increased (Figure 2b). This occurred despite reduced training loads from 2012 to 2013, indicating that this was unlikely due to inappropriate loading. Initially, this was addressed through the prescription of additional stability and balance training, and the implementation of supportive strapping for all players with a history of ankle injury, but no improvement was seen as a result of these measures in 2014. The MDT hypothesized that the emphasis placed on stability and balance training to address both knee and ankle injury burden, may have resulted in additional fatigue in the lower limb, increasing the propensity for injury. Going forward, a minimum effective dose[28] approach was adopted to implementing prehabilitation type training. In line with this approach, the frequency and volume of lower leg balance and stability training was progressively reduced. This yielded incremental improvements in 2015 and 2016.

Following the 2014 injury audit, the complex systems nature of injury occurrence[5,6] became apparent to the MDT. Relationships within the system were non-linear and dynamic in nature with changes that had positive effects in certain areas, resulting in negative effects in other areas. For example, the 2014 injury audit indicated that the shoulder injury mitigation strategy (increased strengthening and skill/technique interventions) had been successful in reducing shoulder injury burden. An unexpected, but related benefit was a reduction in concussion injury burden (Figure 2b). The MDT theorised that because more time had been spent practicing contact skills, players' tackle technique improved, and they were less likely to get their heads into dangerous positions during tackles.

In contrast, the increased emphasis on conditioning and training contact skills did not improve knee injury outcomes during the same period (Figure 2b). The number of contact knee injuries during training remained consistent from 2013 to 2015 (supplementary data), indicating that the changes in training activities did not directly affect knee injury outcomes during training. However, there was a concern that some sort of residual "contact fatigue" from training may be affecting match injury outcomes, although these factors may not be directly relatable. On the balance of evidence, it was decided to maintain the emphasis on contact skills in training, but to try to manage injury risk and fatigue through manipulations of session intensity and duration. Reducing the impact of knee injuries is a challenging performance problem and remains a concern in the current environment.

The 2015 season was the first to demonstrate a reduced team injury burden from 2012. The MDT was satisfied with this result and chose not to implement any further mitigation strategies for fear of triggering new and potentially undesirable feedback loops in the delicate complex system. The team had the lowest injury incidence in South Africa during this season[29]. During the same time period, South African teams on average showed an increase in injury incidence[30], illustrating the effectiveness of the intervention. The 2016 season resulted in further meaningful decreases in team injury burden. During the same period the team attained their best ever competition results (Table 1), demonstrating the positive effect that improved injury outcomes may have had on performance. The multidisciplinary team drew on expertise in coaching, skill acquisition, video analysis, sports medicine and rehabilitation, sport science and strength and conditioning to affect this positive outcome.

A number of research challenges and limitations were present in this research due to the applied setting in which it was conducted. It was not possible to assess season to season injury burden variability prior to study commencement. This was addressed through the determination of confidence limits[13] and magnitude-based inferences[14] to provide confidence that the changes observed were real. No control group was available, but where possible comparisons were made with teams participating in the same competitions[29,30]. In 2013, the team played in a lower standard competition, the effect of this on injury burden is difficult to determine. Furthermore, movement of players between teams could not be controlled, and as such the player group was different for each season.

CONCLUSION

Many sport injury prevention approaches are developed in closed-system, scientific conditions, and as a result transfer poorly into real-world settings[31]. The injury prevention approach described here demonstrated the effectiveness of a multidisciplinary approach to injury prevention within professional team sport setting.

PRACTICAL IMPLICATIONS

This study provides important considerations for those aiming to implement sports injury prevention interventions in applied settings.

- The ability to evolve, learn, and adapt is necessary and desirable.
- Positive impacts may take time (3 years in this case), and perhaps only occur after outcomes have become worse in the short-term as the system adjusts.
- A complex open system may self-regulate, and the multiple components of such a system interact in unpredictable and sometimes hidden or unforeseen ways.

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TABLES

Table 1 – Summary of results of a professional rugby union team across 5 seasons (2012 to 2016)

	Games played	Games won (%)	Points for	Points against	Points different	Super rugby log position	Currie cup log position
2012	27	9 (33%)	621	756	-135	15	2
2013*	23	14 (61%)	920	529	391	-	4
2014	27	15 (56%)	795	658	137	12	2
2015	28	21 (75%)	847	638	209	8	1
2016	27	18 (67%)	994	670	324	2	4
Total	132	77 (58%)	4177	3251	926		

* During this season, the team did not participate in Super Rugby, and played in an alternative competition

FIGURE LEGENDS

Figure 1 – An iterative "sequence of prevention" cycle for reducing sports injury risk. Modified from van Mechelen et al. (1987)

Figure 2 – Injury burden for a professional rugby union team across five successive seasons. a: Total, contact and non-contact injuries, b: Injuries at the six most injurious sites

Data normalised to a 32-week season. *, #, § and ± indicate a greater than 75% likelihood of a real difference (i.e. likely, very likely or most likely) from 2012, 2013, 2014 and 2015 respectively.